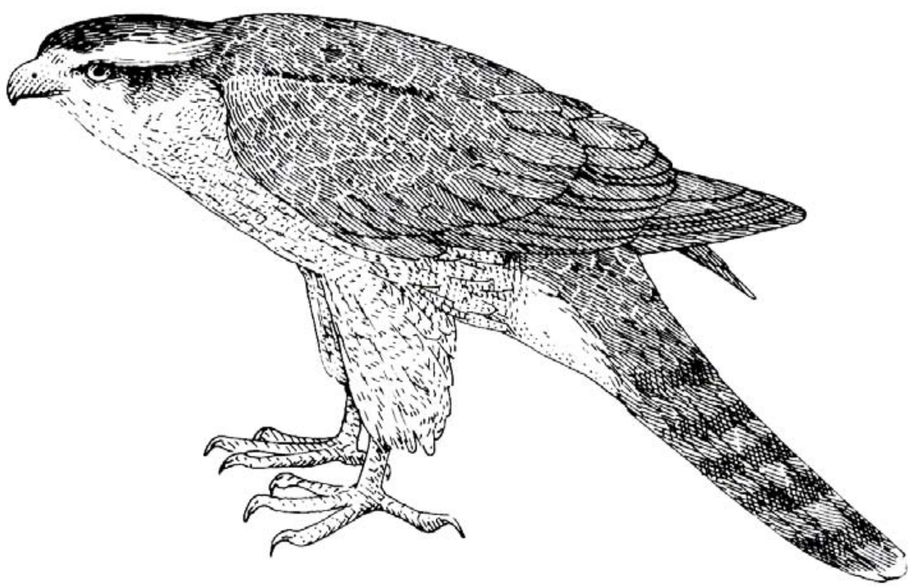
California Wildlife Habitat Relationships Program
California Department of Fish and Game

HABITAT SUITABILITY MODELS FOR USE WITH ARC/INFO: NORTHERN GOSHAWK



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HABITAT SUITABILITY MODELS FOR USE WITH ARC/INFO: NORTHERN GOSHAWK

by

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PREFACE

This document is part of the California Wildlife Habitat Relationships (CWHR) System operated and maintained by the California Department of Fish and Game (CDFG) in cooperation with the California Interagency Wildlife Task Group (CIWTG). This information will be useful for environmental assessments and wildlife habitat management.

The structure and style of this series is basically consistent with the "Habitat Suitability Index Models" or "Bluebook" series produced by the USDI, Fish and Wildlife Service (FWS) since 1981. Moreover, models previously published by the FWS form the basis of the current models for all species for which a "Bluebook" is available. As is the case for the "Bluebook" series, this CWHR series is not copyrighted because it is intended that the information should be as freely available as possible. In fact, it is expected that these products will evolve rapidly over the next decade.

This document consists of two major sections. The Habitat Use Information functions as an up-to-date review of our current understanding regarding the basic habitat requirements of the species. This section typically builds on prior publications, including the FWS "Bluebook" series. However, the Habitat Suitability Index (HSI) Model section is quite different from previously published models. All models in this CWHR series are designed as macros (AML computer programs) for use with ARC/INFO geographic information system (GIS) software running on a UNIX platform. As such, they represent a step up in model realism in that spatial issues can be dealt with explicitly. They are "Level II" models in contrast to the "Level I" (matrix) models initially available in the CWHR System. For example, issues such as habitat fragmentation and distance to habitat elements may be dealt with in spatially explicit "Level II" models. Unfortunately, a major constraint remains the unavailability of mapped habitat information most useful in defining a given species' habitat. For example, there are no readily available maps of snag density. Consequently, the models in this series are compromises between the need for more accurate models and the cost of mapping essential habitat characteristics. It is hoped that such constraints will diminish in time.

While "Level II" models incorporate spatial issues, they build on "Level I" nonspatial models maintained in the CWHR System. As the matrix models are field tested and occasionally modified, these changes will be expressed in the spatial models as well. In other words, the continually evolving "Level I" models are an integral component of the GIS-based, spatial models. To use these "Level II" models one must have (1) UNIX-based ARC/INFO with GRID module, (2) digitized coverages of CWHR habitat types for the area under study and habitat element maps as required for a given species, (3) the AML presented in this document, and (4) a copy of the CWHR database. Digital copies of AMLs are available from the CWHR Coordinator at the CDFG.

Unlike many HSI models produced for the FWS, this series produces maps of habitat suitability with four classes of habitat quality: (1) None; (2) Low; (3) Medium; and

(4) High. These maps must be considered hypotheses in need of testing rather than proven cause and effect relationships, and proper use of the CWHR System requires that field testing be done. The maps are only an initial "best guess" which professional wildlife biologists can use to optimize their field sampling. Reliance on the maps without field testing is risky even if the habitat information is accurate.

The CDFG and CIWTG strongly encourage feedback from users of this model and other CWHR components concerning improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to wildlife management planning. Please send suggested improvements to:

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ACKNOWLEDGMENTS

The primary credit for this document must go to the field biologists and naturalists that have published the body of literature on the ecology and natural history of this species. They are listed in the References section. Ecological information of this sort is generally very expensive and time-consuming to obtain. Yet this basic ecological understanding is exactly what is needed most if the goal of accurately predicting changes in distribution and abundance of a particular species is ever to be achieved. The CWHR System is designed to facilitate the use of existing information by practicing wildlife biologists. We hope it will also stimulate funding for basic ecological research. Funding for producing this model was provided by the California Department of Forestry and Fire Protection and the University of California Agricultural Experiment Station.

We thank Barry Garrision, Karyn Semka, and Sandie Martinez of the California Department of Fish and Game for their assistance in typing, editing, and producing this report.

NORTHERN GOSHAWK (*Accipiter gentilis*)

HABITAT USE INFORMATION

General

The northern goshawk (*Accipiter gentilis*) inhabits coniferous or mixed coniferous forests in western North America (Wattel 1981; American Ornithologists' Union 1983). In California, they breed in the North Coast and Sierra Nevada Ranges, and in the Klamath, Cascade and Warner mountains (Zeiner et al. 1990). In the Sierra Nevada, goshawks breed from the mixed conifer forests at low elevations up to and including high elevation lodgepole pine (*Pinus contorta* var. *murrayana*) forests and eastside ponderosa pine (*Pinus ponderosa*) habitats. Breeding may also occur on Mt. Pinos and in the San Jacinto, San Bernadino, and White mountains (Zeiner et al. 1990). In breeding areas, they are scarce to uncommon yearlong residents, preferring middle to high elevation dense mature coniferous forests. During the winter they are casual visitors along the coast, throughout the foothills, and in northern deserts where they are associated with pinyon (*Pinus* spp.) -juniper (*Juniperus* spp.) and low-elevation riparian habitats (Zeiner et al. 1990).

Food

Goshawks are opportunistic predators taking at least 44 species of forest birds and mammals in western North America (Reynolds et al. 1992). At least 36 species of prey are consumed in California (Schnell 1958; Bloom et al. 1986). Goshawk morphology is characterized by short, rounded wings, and a long tail which are adaptations that enhance flight agility through dense forest (Jones 1979). Prey are caught in the air, on the ground, or in vegetation. An adult goshawk requires approximately 119-150 gm (4.2-5.3 oz) of food per day, or the equivalent of one or two small birds per day (Brown and Amadon 1968).

Nestling birds comprised 61% of the prey items brought to a central Sierra Nevada goshawk nest and accounted for 46% of the biomass of the 88 items fed to the young (Schnell 1958). The five prey items most commonly delivered to the nest and their respective percentages of the total delivered were American robin (*Turdus migratorius*) (31%), Steller's jay (*Cyanocitta stelleri*) (25%), golden-mantled ground squirrel (*Spermophilus lateralis*) (7%), Douglas' squirrel (*Tamiasciurus douglasii*) (6%), and chipmunks (*Tamias* spp.) (Schnell 1958).

A study of prey remains found in territories surrounding California goshawk nests identified 234 prey items representing 31 species (Bloom et al. 1986). By frequency, avian prey constituted 68% of the total with mammals accounting for the remaining 32%. However, lagomorphs and sciurids comprised 49% of the prey species taken and 66% of the total biomass. The five most commonly encountered prey species were Douglas' squirrel (21%), Steller's jay (12%), golden-mantled ground squirrel (9%), northern flicker (*Colaptes auratus*) (7%), and northern flying squirrel (*Glaucomys sabrinus*) (6%) (Bloom et al. 1986).

In eastern Oregon, 56% of the diet of goshawks consisted of birds and 44% were mammals (Reynolds and Meslow 1984). The mean weight of avian prey was 195.5 gm (6.9 oz), and 445.2

gm (15.7 oz) for mammalian prey.

Goshawks forage in mature dense forests, along forest edges, and in clearings (Bent 1937; Bartelt 1977; Hennessy 1978; Jones 1979). The goshawks' relatively large body size and wing span limit their ability to fly in young, dense forests (Fischer 1986). The goshawk is a height-zone generalist, taking prey from the ground-shrub, shrub-canopy, and canopy layers with fewest prey taken from the tree canopy (Reynolds 1979; Reynolds and Meslow 1984). Fischer (1986) found that foraging goshawks in Utah preferred woodlands with large, mature trees. In California, meadows, riparian corridors, and aspen groves are critical habitat for the key prey species taken by goshawks (Bloom et al. 1986). Goshawks have been observed foraging in a wide variety of forest types and conditions (Fischer 1986; Kenward and Widen 1989; Widen 1989) suggesting that foraging habitat may be as closely tied to prey availability as to habitat composition or structure (Kenward and Widen 1989; Reynolds 1989).

Plucking perches are used by nesting goshawks to remove fur and feathers and to dismember prey (Schnell 1958; Eng and Gullion 1962; Jones 1979). Perches are usually located within the nesting territories (Schnell 1958) and consist of stumps, fallen logs, snags, arched trees, rocks, or horizontal tree limbs below the canopy (Bartelt 1977, Reynolds et al. 1982). Bartelt (1977) reports plucking posts to be within 100 m (328 ft) of the nest. Schnell (1958) reported such posts to range from 31-129 m (102-423 ft) from the nest, with a mean distance of 69 m (226 ft). Reynolds (1983) reported a distance range of 27-74 m (89-243 ft) with a mean of 45 m (148 ft). Factors influencing the choice of a plucking post are its sturdiness, height, and accessibility (Schnell 1958).

Water

The availability of open water is an important factor in goshawk nest site selection (Brown and Amadon 1968; Bartelt 1977; Hennessy 1978; Shuster 1980; Reynolds et al. 1982). In California, goshawk nests ranged from 15-1700 m (44-5,576 ft) from water with 75% of the nests located more than 100 m (328 ft) from water (Saunders 1982). In northwestern California, nests ranged from 0-357 m (0-1,171 ft) from water (Hall 1984). Nest sites in northeastern Oregon averaged 199 m (653 ft) from permanent water (Moore and Henny 1983), while in eastern Oregon 74 goshawk nests averaged 119 m (9,390 ft) from water (Reynolds et al. 1982). However, 22 of the 74 nest sites were dry indicating that, though a water source located within the nest stand may be preferred, it is not required (Reynolds et al. 1982).

Cover

Cover requirements are similar to the reproductive needs of the species, which are satisfied by high trees with dense foliage (Reynolds et al. 1982; Saunders 1982; Moore and Henny 1983; Hall 1984). In addition to contributing to the desired microclimate within a nest stand, high foliage densities may reduce predation by providing cover. Cover requirements are detailed under the section below.

Reproduction

Goshawk nest sites may be defined as the area surrounding the nest tree used by a nesting pair during the breeding season (Reynolds et al. 1982). Nest site limits often coincide with boundaries between stands of different age or species composition, or with topographic features such as ridgelines (Reynolds 1983). Goshawks nest in older stands of coniferous, mixed, or deciduous forest characterized by large trees, dense canopies, and northerly aspects in the southern portion of the hawks' range (Bartelt 1977; McGowan 1975; Hennessy 1978; Shuster 1980; Reynolds et al. 1982; Saunders 1982; Hall 1984; Hayward and Escano 1989). Tree species composition among nest sites is highly variable. The elevational range of nesting goshawks varies in Oregon from 580-1,860 m (1903-6,102 ft) (Reynolds and Wight 1978); in northern Utah from 1,737-2649 m (5,699-8,100 ft) (Hennessy 1978); and in northwestern California from 834-1186 m (2,736-3,891 ft) (Hall 1984).

Goshawk nest sites are characterized by a high percentage of canopy cover with estimates ranging from 40-89% (Schnell 1958; Hennessy 1978; Moore 1980; Shuster 1980; Hall 1984; Crocker-Bedford and Chaney 1988; Hayward and Escano 1989). Estimates of percent canopy cover in nest sites on the east side of the Sierra Nevada and in the lodgepole pine stands in eastern Oregon are lower. Canopy closure at 11 nests on the Inyo National Forest ranged from 27-63% (McCarthy 1986). In eastern Oregon, three (4%) of the nests were either in pure, mature lodgepole stands or in stands dominated by mature lodgepole (Reynolds et al. 1982). These nests were characterized by single-layered canopies with an average closure of 38%. Most of the nest sites in eastern Oregon were dense mature conifer stands with a mean canopy closure of 60%. In northern California, the average canopy closure was 77% (range = 53-92%, n = 12) (Saunders 1982). In northwestern California, Hall (1984) found a mean canopy closure of 94% (range = 84-100%, n=10).

Nest sites are commonly located on the lower one-third or at the bottom of slopes with gentle to moderate inclines (Hayward and Escano 1989). Estimates of slope typically range from 0-45%, although goshawks have been found nesting on slopes with inclines as great as 87% (Bartelt 1977; Reynolds 1983; Hall 1984; Hayward and Escano 1989). In eastern Oregon the slope of 59 nest sites averaged 9% while in northeastern Oregon the slope of 34 nest sites averaged 14% (Reynolds et al. 1982; Moore and Henny 1983). In Colorado, nests were located on benches or basins surrounded by steeper slopes. Slopes varied from 0-40% with a mean of 13% (Shuster 1980). In northern California the mean slope was 12% (range = 0-38%) (Saunders 1982), whereas in northwestern California the slopes were more precipitous with a mean of 41% (range = 4-87%) (Hall 1984). Nests in steep areas were usually low on the slope. In the east side Sierra Nevada habitat, they ranged from 0-16% (n = 7) (McCarthy 1986).

Nest sites are usually located on slopes with either northern or eastern exposures or in canyon bottoms sheltered by such slopes (Schnell 1958; Bartelt 1977; Hennessy 1978; Shuster 1980; Reynolds et al. 1982; Saunders 1982; Hall 1984; Hayward and Escano 1989). However, in northeastern Oregon no preference for aspect was found for nests (Moore 1980), and southern exposures were preferred in Alaska (McGowan 1975). Stands on northerly aspects are typically denser and are considered to be more suitable (Reynolds 1983). Dense vegetation in nest sites presumably provides a relatively mild and stable microenvironment, as well as protection from potential goshawk predators such as great-horned owls (*Bubo virginianus*), red-tailed hawks

(*Buteo jamaicensis*), coyotes (*Canis latrans*), bobcats (*Lynx rufus*), and raccoons (*Procyon lotor*) (Reynolds et al. 1982; Moore and Henny 1983).

Nest sites show considerable variation in the presence of understory vegetation and stand structure. Stands range from those containing few mature trees and numerous smaller understory conifers to those with park-like understories of few trees and closed canopies. Nest locations in Oregon are generally found in dense multi-layered stands (Reynolds 1979, 1983), while nests sites in Colorado and California usually have an open park-like understory (Shuster 1980; Saunders 1982; Hall 1984). Stand densities average 450 trees/ha (2.5ac) and range from 270-1,530 trees/ha (2.5 ac)(Bartelt 1977; Reynolds et al. 1982; Hall 1984). Nests are typically built in older forest stands, with nest trees ranging from 20-75 cm dbh (8-30 in) dbh (Eng and Gullion 1962; McGowan 1975; Bartelt 1977; Moore 1980; Reynolds et al. 1982; Hall 1984). In Colorado, nest trees varied from 21-50 cm (8-20 in) dbh (Shuster 1980), while nest trees in Oregon averaged 82 cm (32 in) dbh (Reynolds et al. 1982). In northwestern California, goshawks nested in mature stands with an average tree diameter of 46 cm (18 in) (Hall 1984).

Nest sites are often near clearings, small logging roads, stream beds, or other natural flight paths. Most are within 0.4 km (1,312 ft) of a forest opening that is 0.04-0.4 ha (0.1-1.0 ac) in size (Hennessy 1978; Shuster 1980; Hall 1984).

Interspersion and Composition

Estimates of densities of nesting goshawk pairs range from a high of 1.1 pairs/1,000 ha (2,500 ac) in Arizona (Crocker-Bedford and Chaney, 1988) to a low of 0.2 pairs in Alaska (McGowan 1975). Other reported densities per 1,000 ha (2,500 ac) include 0.4 pairs in Oregon (Reynolds and Wight 1978), 0.7 pairs in northern Colorado (Shuster 1977), and 0.3 pairs in California (Bloom et al. 1986). Gross population estimates have been calculated for California and Nevada by multiplying the number of nesting territories per township by the number of townships with suitable habitat. Oakleaf (1975) estimated that there were a total of 500 active territories in Nevada and Bloom et al. (1986) predicted that there were 1,300 nesting territories in California of which 61% were estimated to be active each year.

Reported home range sizes differ markedly for different studies across North America. Based on an average distance of 5.6 km (3.5 mi) between nests, Reynolds (1979) estimated the home range to be 2,462 ha (6,155 ac). Goshawk densities in Alaska were 1 pair per 4,600 ha (11,500 ac) (McGowan 1975), while Shuster (1976) reported densities of 1 nest/1,330 ha (3,325 ac) in Colorado. The smallest reported home range was 210 ha (525 ac) in Wyoming (Craighead and Craighead 1956). Hunting territory size in South Dakota was estimated to be 1,260 ha (3,150 ac) (Bartlelt 1977), while Eng and Gullion (1962) reported a foraging territory size of 1,250 ha (3,088 ac) in Minnesota.

Special Considerations

Nesting habitat of the goshawk may be adversely affected by intensive forestry practices that reduce the availability of mature forests (Reynolds et al. 1992). Habitat alteration and/or destruction are serious threats to all *Accipiter* hawks (White 1974). Based on the area used by nesting adults and fledged young, Reynolds et al. (1982) recommended that 8 ha (20 ac) of forest be left unharvested around goshawk nests to protect the site.

Planning for potential nest stands should also provide for alternate nest sites because goshawks may not use the same nest in consecutive years (Crocker-Bedford and Chaney 1988). Reynolds (1983) suggested that at least two potential nest sites, one active and one alternate, should be available within each goshawk home range. Alternate nest sites should be 0.5-0.8 km (0.3-0.4 mi) apart (Reynolds et al. 1982). All sites considered for potential nest stands should have the conditions of slope, aspect, and stand composition preferred by goshawks.

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area.

The California Wildlife Habitat Relationships (CWHR) System (Airola 1988; Mayer and Laudenslayer 1988; Zeiner et al. 1990) contains habitat ratings for each habitat type predicted to be occupied by northern goshawks in California.

Season.

This model is designed to predict the suitability of habitat for northern goshawks throughout the year. The model works best at predicting habitat suitability for breeding habitat.

Cover types.

This model can be used anywhere in California for which an ARC/INFO map of CWHR habitat types exists. The CWHR System contains suitability ratings for reproduction, cover, and feeding for all habitats Northern Goshawks are predicted to occupy. These ratings can be used in conjunction with the ARC/INFO habitat map to model wildlife habitat suitability.

Minimum habitat area.

Minimum habitat area is defined as the minimum amount of contiguous habitat required before a species will occupy an area. The northern goshawk is a large, relatively mobile species. This model assumes that one quarter home range of contiguous high quality habitat must be present for northern goshawks to maintain a population during the breeding season. This model makes that the assumption that multiple areas of high quality habitat are available to the goshawks in the immediate area. If this is not true, the model will overestimate the suitability of the area for northern goshawks.

Verification level.

The spatial model presented here has not been verified in the field. The CWHR suitability values used are based on a combination of literature searches and expert opinion. We strongly encourage field testing of both the CWHR database and this spatial model.

Model Description

Overview.

This model uses CWHR habitat type as the main factor determining suitability of an area for this species. In addition, distance to water is used to adjust the suitability of the area.

A CWHR habitat type map must be constructed in ARC/INFO GRID format as a basis for the model. The GRID module of ARC/INFO was used because of its superior functionality for spatial modeling. Only crude spatial modeling is possible in the vector portion of the ARC/INFO program, and much of the modeling done here would have been impossible without the abilities of the GRID module. In addition to more

sophisticated modeling, the GRID module's execution speed is very rapid, allowing a complex model to run in less than 30 minutes.

The following sections document the logic and assumptions used to interpret habitat suitability.

Cover component.

A CWHR habitat map must be constructed. The mapped data (coverage) must be in ARC/INFO GRID format. A grid is a GIS coverage composed of a matrix of information. When the grid coverage is created, the size of the grid cell should be determined based on the resolution of the habitat data and the home range size of the species with the smallest home range in the study. You must be able to map the home range of the smallest species with reasonable accuracy. However, if the cell size becomes too small, data processing time can increase considerably. We recommend a grid cell size of 30 m (98 ft). Each grid cell can be assigned attributes. The initial map must have an attribute identifying the CWHR habitat type of each grid cell. A CWHR suitability value is assigned to each grid cell in the coverage based on its habitat type. Each CWHR habitat is rated as high, medium, low or of no value for each of three life requisites: reproduction; feeding; and cover. The geometric mean value of the three suitability values was used to determine the base value of each grid cell for this analysis.

Distance to water.

No water requirement was found for northern goshawks.

Species' distribution.

The study area must be manually compared to the range maps in the CWHR Species Notes (Zeiner et al. 1990) to ensure that it is within the species' range. All grid cells outside the species' range have a suitability of zero.

Spatial analysis.

Ideally a spatial model of distribution should operate on coverages containing habitat element information of primary importance to a species. For example, in the case of woodpeckers, the size and density of snags as well as the vegetation type would be of great importance. For many small rodents the amount and size of dead and down woody material would be important. Unfortunately, the large cost involved in collecting microhabitat (habitat element) information and keeping it current makes it likely that geographic information system (GIS) coverages showing such information will be unavailable for extensive areas into the foreseeable future.

The model described here makes use of readily available information such as CWHR habitat type, elevation, slope, aspect, roads, rivers, streams and lakes. The goal of the model is to eliminate areas that are unlikely to be utilized by the species and lessen the value of marginally suitable areas. It does not attempt to address all the microhabitat issues discussed above, nor does it account for other environmental factors such as toxins, competitors or predators. If and when such information becomes available, this model could be modified to make use of it.

In conclusion, field surveys will likely discover that the species is not as widespread or abundant as predictions by this model suggest. The model predicts potentially available habitat. There are a variety of reasons why the habitat may not be utilized.

Definitions.

Home Range: the area regularly used for all life activities by an individual during the season(s) for which this model is applicable.

Dispersal Distance: the distance an individual will disperse to establish a new home range. In this model it is used to determine if Potential Colony Habitat will be utilized.

Day to Day Distance: the distance an individual is willing to travel on a daily or semi-daily basis to utilize a distant resource (Potential Day to Day Habitat). The distance used in the model is the home range radius. This is determined by calculating the radius of a circle with an area of one home range.

Core Habitat: a contiguous area of habitat of medium or high quality that has an area greater than one half a home range in size. This habitat is in continuous use by the species. The species is successful enough in this habitat to produce offspring that may disperse from this area to the Colony Habitat and Other Habitat.

Potential Colony Habitat: a contiguous area of habitat of medium or high quality that has an area between one quarter and one half a home range in size. It is not necessarily used continuously by the species. The distance from a core area will affect how often Potential Colony

Habitat is utilized.

Colony Habitat: Potential Colony Habitat that is within the dispersal distance of the species. These areas receive their full original value unless they are further than three home range radii from a core area. These distant areas receive a value of low since there is a low probability that they will be utilized regularly.

Potential Day to Day Habitat: an area of high or medium quality habitat less than one home range, or habitat of low quality of any size. This piece of habitat alone is too small or of inadequate quality to be Core Habitat.

Day to Day Habitat: Potential Day to Day Habitat that is close enough to Core or Colony Habitat can be utilized by individuals moving out from those areas on a day to day basis. The grid cell must be within Day to Day Distance of Core or Colony Habitat.

Other Habitat: contiguous areas of low value habitat larger than two home ranges in size, including small areas of high and medium quality habitat that may be imbedded in them, are included as usable habitat by the species. Such areas may act as “sinks” because long-term reproduction may not match mortality.

The table below indicates the specific distances and areas assumed by this model.

Distance variables:	in Oregon Meters	Feet
Dispersal Distance	60,916	199,851
Day to Day Distance/ Home Range radius	2,538	8,327

Area variables:	Hectares	M^2	Acres	Ft^2
Home Range	2,024	20,235,000	5,000	217,800,000
Core Habitat	1,012	10,117,500	2,500	108,900,000

Application of the Model

A copy of the ARC/INFO AML can be found in Appendix 1. The steps carried out by the macro are as follows:

1. **Determine Core Habitat**: this is done by first converting all medium quality habitat to high quality habitat and removing all low value habitat. Then contiguous areas of habitat are grouped into regions. The area of each of the regions is determined. Those large enough (one half home range) are maintained in the

Core Habitat coverage. If no Core Habitat is identified then the model will indicate no suitable habitat in the study area.

2. **Identify Potential Colony Habitat**: using the coverage from Step 1, determine which regions are one quarter to one half home range in size. These are Potential Colonies.

3. **Identify Potential Day Use Habitat**: using the coverage derived in Step 1, determine which areas qualify as Potential Day to Day Habitat.

4. **Calculate the Cost Grid**: since it is presumed to be more difficult for animals to travel through unsuitable habitat than suitable habitat we use a cost grid to limit travel based on habitat suitability. The cost to travel is one for high or medium quality habitat. This means that to travel 1 m through this habitat costs 1 m of Dispersal Distance. The cost to travel through low quality habitat is two and unsuitable habitat costs four. This means that to travel 1 m through unsuitable habitat costs the species 4 m of Dispersal Distance.

5. **Calculate the Cost Distance Grid**: a cost distance grid containing the minimum cost to travel from each grid cell to the closest Core Habitat is then calculated using the Cost Grid (Step 4) and the Core Habitat (Step 1).

6. **Identify Colony Habitat**: based on the Cost Distance Grid (Step 5), only Potential Colony Habitat within the Dispersal Distance of the species to Core Habitat is retained. Colonies are close enough if **any** cell in the Colony is within the Dispersal Distance from Core Habitat. The suitability of any Colony located further than three home range radii from a Core Habitat is changed to low since it is unlikely it will be utilized regularly.

7. **Create the Core + Colony Grid**: combine the Core Habitat (Step 1) and the Colony Habitat (Step 6) and calculate the cost to travel from any cell to Core or Colony Habitat. This is used to determine which Potential Day to Day Habitat could be utilized.

8. **Identify Day to Day Habitat**: grid cells of Day to Day Habitat are only accessible to the species if they are within Day to Day Distance from the edge of the nearest Core or Colony Habitat. Add these areas to the Core + Colony Grid (Step 7).

9. **Add Other Habitat**: large areas (two home ranges in size) of low value habitat, possibly with small areas of high and medium habitat imbedded in them may be utilized, although marginally. Add these areas back into the Core + Colony + Day to Day Grid (Step 8), if any exist, to create the grid showing areas that will potentially be utilized by the species. Each grid cell contains a one if it is utilized and

a zero if it is not.

10. **Restore Values**: all areas that have been retained as having positive habitat value receive their original geometric mean value from the original geometric value grid (see *Cover component* section) with the exception of distant colonies. Distant colonies (colonies more than three home range radii distant) have their value reduced to low because of the low likelihood of utilization.

Problems with the Approach

Cost.

The cost to travel across low suitability and unsuitable habitat is not known. It is likely that it is quite different for different species. This model incorporates a reasonable guess for the cost of movement. A small bird will cross unsuitable habitat much more easily than a small mammal. To some extent differences in vagility between species is accounted for by different estimates of dispersal distances.

Dispersal distance.

The distance animals are willing to disperse from their nest or den site is not well understood. We have used distances from studies of the species or similar species when possible, otherwise first approximations are used. More research is urgently needed on wildlife dispersal.

Day to day distance.

The distance animals are willing to travel on a day to day basis to use distant food sources has not been quantified for most species. This issue is less of a concern than dispersal distance since the possible distances are much more limited, especially with small mammals, reptiles, and amphibians. Home range size is assumed to be correlated with this coefficient.

SOURCES OF OTHER MODELS

Fowler (1988) developed a habitat capability model for the northern goshawk. The model integrates cover and reproductive requirements. Variables used in the model are habitat type, canopy closure, stand size, slope and aspect.

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APPENDIX 1: Northern Goshawk Macro

```
/*          NORTHERN GOSHAWK

/* nghmodel.aml - This macro creates an HSI coverage for the
/*              Northern Goshawk in the California Sierra.

/* Version:  Arc/Info 6.1 (Unix), GRID-based model.

/* Authors:  Irene Timossi, Sarah Miller, Wilde Legard,
/*          and Reginald H. Barrett
/*          Department of Forestry & Resource Management
/*          University of California, Berkeley

/* Note:  the user of this macro must have a thorough understanding
/*       of ARC/INFO GRID before attempting to interpret this macro.
/*       (See the ARC/INFO GRID Command References manual, ESRI,
/*       Redlands, CA).

/*       The user must also have access to the documentation which
/*       accompanies this macro:  Habitat Suitability Models for Use
/*       with ARC/INFO:  Northern Goshawk.

/* Revision: 7/1/94

/* ------------------------------------------------------------------

/* convert .ID to uppercase for info manipulations

&setvar .ID [translate %.ID%]

/* Start Grid

grid

/*

&type (1)  Initializing Constants...

/*   Homerange: the size of the species' homerange.

/*   CoreReq: how much habitat is required for 1/2 a core area.  In this
/*   case 1/4 of the home range is used.

/*   DayPay: The amount the species is willing to pay traveling on
/*   a day-to-day basis.  Used to determine the area utilized on a
/*   day-to-day basis.

/*   DispersePay: Distance traveled when dispersing.  The amount
/*   the animal is willing to pay when dispersing from a core area.

/*   High:  The value in the WHR grid which indicates high quality habitat.

/*   Medium:  The value in the WHR grid which indicates medium quality habitat.
```

```
/*   Low:  The value in the WHR grid which indicates low quality habitat.

/*   None:  The value in the WHR grid which indicates habitat of no value.

/*   SpecCode: The WHR code for the species

/*   AcreCalc:  The number needed to convert square units
/*              (feet or meters) to acres.


&setvar SpecCode = B117

&if %.Measure% = Meters &then
  &goto Meters
&else
  &goto Feet

&label Meters

&setvar Homerange      = 20235000
&setvar CoreReq        = %Homerange% / 4
&setvar DayPay         = 2538
&setvar DispersePay    = 60916
&setvar AcreCalc       = 4047

&goto Begin

&label Feet

&setvar Homerange      = 217800000
&setvar CoreReq        = %Homerange% / 4
&setvar DayPay         = 8327
&setvar DispersePay    = 199851
&setvar AcreCalc       = 43560


&label Begin

&setvar High          = 3
&setvar Medium        = 2
&setvar Low           = 1
&setvar None          = 0

/*   The following global variables are declared in the menu:

/*  .WHRgrid (WHR grid name): the name of the grid containing all
/*   the WHR information.

/*  .Bound (Boundary grid name): the grid containing only the
/*   boundary of the coverage. All cells inside the boundary
/*   have a value of 1. All cells outside the boundary must
/*   have a value < 1.

/*  .ID (Identifier): a 1 to 4 character code used to identify
/*   the files produced by this program. You may prefer
/*   to use an abbreviation of the species' common name
```

```
/*   (e.g. use `fis1` for fisher).

/*  .SizeOfCell (Cell size): the size (width) of the cells
/*   used in the coverage grids. All grids used in the
/*   analysis must have the same cell size.

/*  .Measure:  the units the coverage is measured in (feet or meters).


&type (2)  Creating working grid of geometric means...

/*    Create a Geometric Means grid (%.ID%Geom) for the species by
/*    copying these values from the WHR grid.

%.ID%Geom = %.WHRgrid%.%SpecCode%_G

/*

&type (3)  Changing %Medium% value cells to %High% value for Merge grid...

/*    Create a grid (%.ID%Merge) merging Medium and High
/*    value cells from the Geometric mean grid (%.ID%Geom),
/*    while leaving the value of other cells (Low and None) unchanged.
/*    Merge by changing the value of all medium cells to High.
/*    This creates of grid of high value habitat (potential core) and
/*    low value habitat.

%.ID%Merge = con(%.ID%Geom == %Medium%,%High%,%.ID%Geom)

/*

&type (4)  Converting Merge grid zones into a Region grid...

/*    Convert the zones of the merge grid (%.ID%Merge) into
/*    unique regions (%.ID%Region). These will be used later
/*    to create core, colony, and day-to-day areas.  This allows
/*    the calculation of areas of contiguous habitat.

%.ID%Region = regiongroup(%.ID%Merge)

/*

&type (5)  Calculating the area of Region grid zones...

/*    Calculate the area of the zones (%.ID%ZoneArea) on the region
/*    grid (%.ID%Region).

%.ID%ZoneArea = zonalarea(%.ID%Region)

/*

&type (6)  Creating a Core Area grid...

/*    Extract areas from the zonal area grid (%.ID%ZoneArea)
/*    suitable for core areas (%.ID%Core). Core areas are defined
/*    as the Medium+High zones in the merge grid (%.ID%Merge)
```

```
/*    with an area of at least one quarter home range (%CoreReq%).
/*    Set their value = 1.

if (%.ID%Merge == %High% and %.ID%ZoneArea >= %CoreReq% * 2)
  %.ID%Core = 1
endif

&if not [exists %.ID%Core -vat] &then
  &goto END

/*

&type (7)  Creating a Colony grid...

/*    Extract areas from the zonal area grid (%.ID%zoneArea)
/*    possibly suitable for colonization (%.ID%ColTemp).
/*    Colony areas are defined as Low or Medium+High zones
/*    in the Merge grid (%.ID%Merge) with an area of between one
/*    quarter and one half a home range (%CoreReq%). Set their value = 1.

/*    Then set all nodata values in the grid to zero (%.ID%Colony).

docell
  if (%.ID%Merge == %High%)
    if (%.ID%ZoneArea > %CoreReq% and %.ID%ZoneArea < %CoreReq% * 2)
      %.ID%ColTemp = 1
    endif
  endif
end

%.ID%Colony = con(isnull(%.ID%ColTemp),0,%.ID%ColTemp)

/*

&type (8)  Creating a Day-to-Day Use grid...

/*    Create a grid based on the values in the zonal
/*    area grid (%.ID%ZoneArea) and merge grid (%.ID%Merge)
/*    suitable for day-to-day use (%.ID%DayToDay). Day-to-day use
/*    areas are defined as Low if the area is less than two
/*    homeranges in size or Medium+High zones in the
/*    merge grid (%.ID%Merge) with an area of less than one quarter home
/*    range (%CoreReq%). Set their value = 1.

if ((%.ID%Merge > %Low% and %.ID%ZoneArea <= %CoreReq%) or ~
    (%.ID%Merge == %Low% and %.ID%ZoneArea < %CoreReq% * 2))
  %.ID%DayToDay = 1
else
  %.ID%DayToDay = 0
endif

/*

&type (9)  Creating a Cost Grid based on habitat value...

/*     Using the merge grid (%.ID%Merge), create a cost grid (%.ID%Cost)
```

```
/*    based on the habitat-value. Cost represents the relative
/*    resistance a species has to moving across different quality
/*    habitat:   Habitat-value   Cost
/*               None            4
/*               Low             2
/*               Medium+High     1

if (%.ID%Merge == %None%)
  %.ID%Cost = 4
else if (%.ID%Merge == %Low%)
  %.ID%Cost = 2
else if (%.ID%merge == %High%)
 %.ID%Cost = 1
endif

/*

&type (10) Calculating cost to travel from Core Areas...

/*    Calculate the cost to travel the distance (%.ID%CostDist)
/*    from the nearest core area source (%.ID%Core) using the cost
/*    grid (%.ID%Cost).
/*

%.ID%CostDist = CostDistance(%.ID%Core,%.ID%Cost)

/*

&type (11) Calculating which Colony areas are Cost Effective...

/*    If Colony Areas exist...
/*    Find the areas in the Colony grid (%.ID%Colony) that could
/*    be colonized from the core areas:

/*    Assign costs to all cells in the Colony areas (%.ID%Colony)
/*    from the Cost grid (%.ID%CostDist). Zero surrounding NODATA areas.

/*    Make each colony a separate zone (%.ID%ZoneReg) using
/*    the regiongroup command.

/*    Use zonalmin to find the minimum cost to arrive at each
/*    colony (%.ID%ZoneMin).

/*    Set all NODATA cells to zero in %.ID%ZoneMin to produce
/*    %.ID%ColZer1.

/*    To find out which of the potential colonies can be utilized,
/*    determine which have a cost that is equal to or less than
/*    DispersePay. If the cost to get to a colony is less than
/*    or equal to DispersePay, keep it in grid %.ID%Col.

/*    Fill the null value areas in %.ID%Col with zeros to create %.ID%ColZer2


&if not [exists %.ID%ColTemp -vat] &then
 &goto SkipColony
```

```
%.ID%ColDist = con(%.ID%Colony > 0,%.ID%CostDist,0)
%.ID%ZoneReg = regiongroup(%.ID%Colony)
%.ID%ZoneMin = zonalmin(%.ID%ZoneReg,%.ID%ColDist)
%.ID%ColZer1 = con(isnull(%.ID%ZoneMin),0,%.ID%ZoneMin)

if (%.ID%ColZer1 <= %DispersePay% and %.ID%ColZer1 > 0)
  %.ID%Col = %.ID%Colony
else
  %.ID%Col = %.ID%Core
endif

%.ID%ColZer2 = con(isnull(%.ID%Col),0,%.ID%Col)

/*

&type (12)  Creating Core + Colony grid...

/*    If colonies exist....
/*    Create a grid (%.ID%ColCore) that combines the core
/*    (%.ID%Core) and colony (%.ID%Colony) grids.
/*    This grid will be used to analyze day-to-day use.


if (%.ID%Colony == 1)
  %.ID%ColCore = 1
else
  %.ID%ColCore = %.ID%Core
endif

&label SkipColony


&type (13)  Calculate cost to travel from Core and Colony Areas...

/*    If colonies exist...
/*    Calculate the cost to travel the distance (%.ID%CostDis2)
/*    from the nearest core or colony area source (%.ID%ColCore).
/*    Otherwise just copy the %.ID%CostDist grid to use for Day-to-Day
/*    analysis.

&if not [exists %.ID%ColTemp -vat] &then
  %.ID%CostDis2 = %.ID%CostDist
&else %.ID%CostDis2 = CostDistance(%.ID%ColCore,%.ID%Cost)

/*

&type (14) Calculating which Day-to-Day areas are Cost Effective...

/*    This step adds the utilized Day-to-Day cells to the
/*    Core + Colony Area grid (%.ID%ColZer2) to produce the
/*    %.ID%Day1 grid.

/*    Use the Core + Colony Cost grid (%.ID%CostDis2)to find out
/*    what can actually be used day-to-day (any cell with
/*    a cost of DayPay or less).
```

```
/*    Retain any cell in the Day-to-Day grid (%.ID%DayToDay) with
/*    a cost less than or equal to DayPay and greater than zero.

/*    If the Distance-Cost grid (%.ID%CostDis2) = 0,
/*    it is part of the Core or Colony Area and
/*    should gets its value from Core + Colony Area
/*    grid (%.ID%ColZer2).

&if not [exists %.ID%ColTemp -vat] &then
   &goto SkipCol2

if (%.ID%CostDis2 <= %DayPay% and %.ID%CostDis2 > 0)
  %.ID%Day1 = %.ID%DayToDay
else
  %.ID%Day1 = %.ID%ColZer2
endif

&goto Continue

&label SkipCol2

if (%.ID%CostDis2 <= %DayPay% and %.ID%CostDis2 > 0)
  %.ID%Day1 = %.ID%DayToDay
else
  %.ID%Day1 = %.ID%Core
endif

&label Continue

&type (15)  Finding Other Areas That May Be Utilized....

/*    This step picks up any large low value areas and any small
/*    medium or high value polygons that are imbeded
/*    in them.

/*    First mark any low value areas with an area > CoreReq * 2 to
/*    create %.ID%Low using the Geometric mean (%.ID%Geom) grid
/*    and the Zone Area (%.ID%ZoneArea) grid.

/*    if %.ID%Low is all nodata, skip the rest of these steps.

/*    Add the medium and high grid cells that are less than 1 HR in
/*    size and are not used day-to-day to the %.ID%Low grid to
/*    create %.ID%LowPlus

/*    Split all %.ID%LowPlus areas into separate regions (%.ID%LowReg)

/*    Calculate the area of the regions (%.ID%LowArea).

/*    Keep any region in %.ID%LowArea with an area > 2 * CoreReq (%.ID%Util).

/*    Change any null values in %.ID%Util to zeros (%.ID%LowZero).


if (%.ID%Geom == %Low% and %.ID%ZoneArea >= %CoreReq% * 2)
  %.ID%Low = 1
```

```
endif

&if not [exists %.ID%Low -vat] &then
  &goto SkipLow

if ((%.ID%CostDis2 >= %DayPay%) and (%.ID%Geom > 1) and ~
    (%.ID%ZoneArea < %CoreReq%))
  %.ID%LowPlus = 1
else
  %.ID%LowPlus = %.ID%Low
endif

%.ID%LowReg = regiongroup(%.ID%LowPlus)

%.ID%LowArea  = zonalarea(%.ID%LowReg)

if (%.ID%LowArea >= %CoreReq% * 2)
  %.ID%Util = 1
else
  %.ID%Util = 0
endif


%.ID%LowZero = con(isnull(%.ID%Util),0,%.ID%Util)


/*

&type (16) Adding other utilized habitat...

/*     Add the Other Utilized habitat (%.ID%LowZero) to the %.ID%Day1 coverage
/*     to produce the %.ID%All coverage.

if (%.ID%LowZero == 1)
  %.ID%All = %.ID%LowZero
else
  %.ID%All = %.ID%Day1
endif

&goto Value

&label SkipLow

%.ID%All = %.ID%Day1

&label Value

&type (17) Creating a Value grid...

/*     For any cell in %.ID%All that has a value of 1, store the suitability
/*     value from the Geometric mean grid (%.ID%Geom) to the %.ID%Value grid.

/*     Other cells inside the boundary (%.Bound%) get a value of 0.

/*
```

```
if (%.ID%All == 1)
  %.ID%Value = %.ID%Geom
else if (%.Bound% == 1)
  %.ID%Value = 0
endif

/*

&type (18)  Creating an HSI grid...

/*     if Colonies exist....
/*     For any cell that was part of a colony that is further than
/*     3 times the HR radius (DayPay) away from a core area, set the suitability
/*     to Low.  Distant colonies lose value because of their small size.
/*     This step produces grid %.ID%Collow.

/*     Set all NODATA values in %.ID%Collow to zero in %.ID%ColZer3.

/*     Find any day-to-day use areas (%.ID%DayToDay) that are being
/*     utilized (%.ID%ColZer3).  If they are further than four homeranges
/*     from a core area (%.ID%CostDist), they are utilized from a distant
/*     colony and their value will be decreased to Low in %.ID%Day2.


/*     Then change nulls to zero in %.ID%ValZero

/*     Keep all data within the boundary; call this final grid HSI.

&if not [exists %.ID%ColTemp -vat] &then
   &goto SkipCol3

if (%.ID%ColZer1 >= %DayPay% * 3)
  %.ID%Collow = %Low%
else
  %.ID%Collow = %.ID%Value
endif

%.ID%ColZer3 = con(isnull(%.ID%Collow),0,%.ID%Collow)

if ((%.ID%CostDist > %DayPay% * 4) and (%.ID%ColZer3 > 0) and ~
    (%.ID%DayToDay == 1))
  %.ID%Day2 = 1
else
  %.ID%Day2 = %.ID%ColZer3
endif

&goto HSI

&label SkipCol3

%.ID%Day2 = %.ID%Value

&label HSI

%.ID%valzero = con(isnull(%.ID%Day2),0,%.ID%Day2)
```

```
if (%.Bound% == 1)
  %.ID%hsi = %.ID%valzero
endif

/*

&type (19)  Quiting from GRID and adding the acres field.....

/*     Quit from GRID (Q), then run additem to add an acre item to
/*     the HSI grid vat file (%ID%HSI.vat). Reindex on value when done.

Q
additem %.ID%HSI.vat %.ID%HSI.vat acres 10 10 i
indexitem %.ID%HSI.vat value

/*

&type (20)  Calculating acres.....

/*    Use INFO to calculate the acreage field: Multiply the number
/*    of cells by the cell size squared and divide by the number of
/*    square meters per acre (4047). Reindex on value when done.

&data arc info
arc
select %.ID%HSI.VAT
CALC ACRES = ( COUNT * %.SizeOfCell% * %.SizeOfCell% ) / %AcreCalc%
Q STOP

&END

indexitem %.ID%HSI.vat value

&goto NODELETE

/*

&type  (21) Killing all intermediate coverages before ending macro...


&label NODELETE

/* &goto OKEND

grid

kill %.ID%Geom
kill %.ID%Merge
kill %.ID%Region
kill %.ID%ZoneArea
kill %.ID%Core
kill %.ID%ColTemp
kill %.ID%Colony
kill %.ID%DayToDay
kill %.ID%Cost
kill %.ID%CostDist
```

```
kill %.ID%ColDist
kill %.ID%ZoneReg
kill %.ID%ZoneMin
kill %.ID%ColZer1
kill %.ID%Col
kill %.ID%ColZer2
kill %.ID%ColCore
kill %.ID%CostDis2
kill %.ID%Day1
kill %.ID%Low
kill %.ID%LowPlus
kill %.ID%LowReg
kill %.ID%LowArea
kill %.ID%Util
kill %.ID%LowZero
kill %.ID%All
kill %.ID%Value
kill %.ID%Collow
kill %.ID%ColZer3
kill %.ID%Day2
kill %.ID%valzero

q

&goto OKEND

&label END
&type **
&type **
&type NO CORE AREAS EXIST, EXITING MACRO
&type **
&type **

kill %.ID%Core
kill %.ID%Region
kill %.ID%ZoneArea
kill %.ID%Merge
kill %.ID%Geom

quit

&label OKEND

&type -------------- All done! ----------------
&return
```